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AUTHORITY
EO 10501, 5 Nov 1953; usnswc ltr, 5 jun 1975

U. S. NAVAL PROVING GROUND
DAHLGREN, VIRGINIA

REPORT NO. 660

TED PROJECT NO. NPG AR 8208

3rd Partial Report

UNBONDED NYLON FRAGMENT ARMOR FABRIC BALLISTIC SURVEILLANCE TEST OF

FINAL Report

Task Assignment TED PROJECT NPG AR 8208

Copy No. ____ Classification [redacted]

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(14) NPG [redacted]-660

U. S. NAVAL PROVING GROUND
DAHLGREN, VIRGINIA

UNCLASSIFIED

(21)

~~Third~~ Partial Report. no. 13

on

TED ~~Project No.~~ NPG-AR-8208

- -

(9) Final Report,

on

(6) Unbonded Nylon Fragment Armor Fabric;

Ballistic Surveillance Test of.

(10) R. T. / R. L. L.

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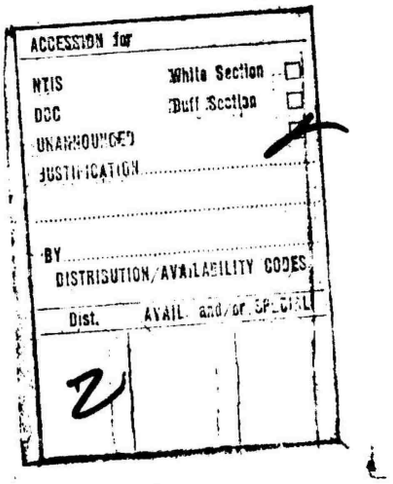
(11) 12 OCT 1950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2

NAVAL PROVING GROUND ARMOR FRAGMENT RESISTANT SHEET FIRING RECORD

[redacted]

SHEET NO.
ENCL. ( )
S13-1(5-)

UNCLASSIFIED

Manufacturer :
Type of Panels: [illegible] (NFD-[illegible]) [illegible]
No. Submitted : 6
Date of Mfg. :
Contract : Experimental
Chemical Composition
Cloth : [illegible]
Resin : [illegible]
Resin Content: [illegible]

Physical Properties
Size of Sample: 23"x24"
Av. Thickness :
Av. Wt.#/sq.ft: 1.30
Density :
Mod. of Elast.:
Flex. Strength:

Method of Processing
No. of Plies : 15
Layup of Plies: STRAIGHT

Molding Cycle : NONE

Proj : 20MM HE [illegible]
Gun : 850003
Range : 1
Obl. : 0
RC : 35
Av.C (3 poorest panels: 32
Result

AV. ALL - 29

Specs : 05-3563
Group : A
Date : 1 Sept 1950

T62 [illegible]

Panel	Unit Wt	Bullet	Charge	Str.Vel.	Condition of Plate	Trigger Plate Dispersion	Av. Ga.
1	1.30	20MM	425	2709	25 Holes	7½" Hole 5" High 2" Right	0."122
2	1.30	20MM	425	2717	27 Holes	6½" Hole 2" High 2" Left	0."122
3	1.30	20MM	425	2727	34 Holes	8½" Hole 6" High 2" Left	0."124
4	1.30	20MM	425	2722	26 Holes	7½" Hole 3" High	0."124
5	1.30	20MM	424	2717	30 Holes	7½" Hole 4" High 1½" Left	0."123
6	1.30	20MM	424	2696	32 Holes	8" Hole 1" Left	0."122

Note: Ballistic Test Performed: Ambient Temperature 86°F

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NAVAL PROVING GROUND — ARMOR FRAGMENT RESISTANT (VEST) FIRING RECORD — R-E-S-T-R-I-C-T-E-D

SHEET NO.
ENCL. ( )
S13-1(5-)

Manufacturer :
Type of Panels: NYLON (NFD-202/1) UNBONDED
No. Submitted : 6
Date of Mfg. :
Contract : EXPERIMENTAL
Chemical Composition
Cloth : Nylon Basket Weave
Resin :
Resin Content: ---

Method of Processing
No. of Plies : 21
Layup of Plies: straight

Molding Cycle : none

Physical Properties
Size of Sample: 23"X24"
Av. Thickness :
Av. Wt.#/sq.ft: 1.82
Density :
Mod. of Elast.:
Flex. Strength:

Proj : 20MM HE MK 3 MK26-1 Fuze
Gun : 850003
Range : 1
Obl. : 0°
RC : 22
Av.C (3 poorest panels: 18.7 AV. ALL - 18.7
Result

Specs : OS-3563
Group : B
Date : 1 Sept. 1950

Panel	Unit Wt	Bullet	Charge	Str.Vel.	Condition of Plate	Trigger Plate Dispersion	Av. Ga.
1	1.82	20MM	423	2225	21 Holes	7" Hole 4" High 3" Left	0".121
2	1.82	"	423	2709	22 Holes	8" Hole 1" Low 1" Left	0".123
3	1.82	"	423	2714	17 Holes	8" Hole 3 High 1" Left	0".123
4	1.82	"	423	2699	16 Holes	7½ Hole 1" High	0".122
5	1.82	"	423	2720	22 Holes	8" Hole 2" High 1" Left	0".121
6	1.82	"	423	2699	14 Holes	8" Hole 3" High 1" Left	0".121

Note: Ballistic Test Performed: Ambient Temperature 86°F

NAVAL PROVING GROUND — ARMOR FRAGMENT RESISTANT SHEET FIRING RECORD R-E-S-T-R-I-C-T-E-D — SHEET NO. ENCL. ( ) S13-1(5-)

Manufacturer :
Type of Panels: NYLON (AFP-202/1) UNBONDED
No. Submitted : 6
Date of Mfg. :
Contract : EXPERIMENTAL
Chemical Composition
Cloth : NYLON BASKET WEAVE
Resin : ---
Resin Content: ---

Physical Properties
Size of Sample: 23"X24"
Av. Thickness :
Av. Wt.#/sq.ft: 2.78
Density :
Mod. of Elast.:
Flex. Strength:

Method of Processing
No. of Plies : 32
Layup of Plies: Straight

Molding Cycle : None

Proj : 20MM HE MK 3 MK 26-1 FUZE
Gun : 850003
Range : 1
Obl. : 0°
RC : 8
Av.C (3 poorest panels: 9.7
Result

Specs : OS-3563
Group : C
Date : 1 Sept. 1950

AV. ALL - 8.3

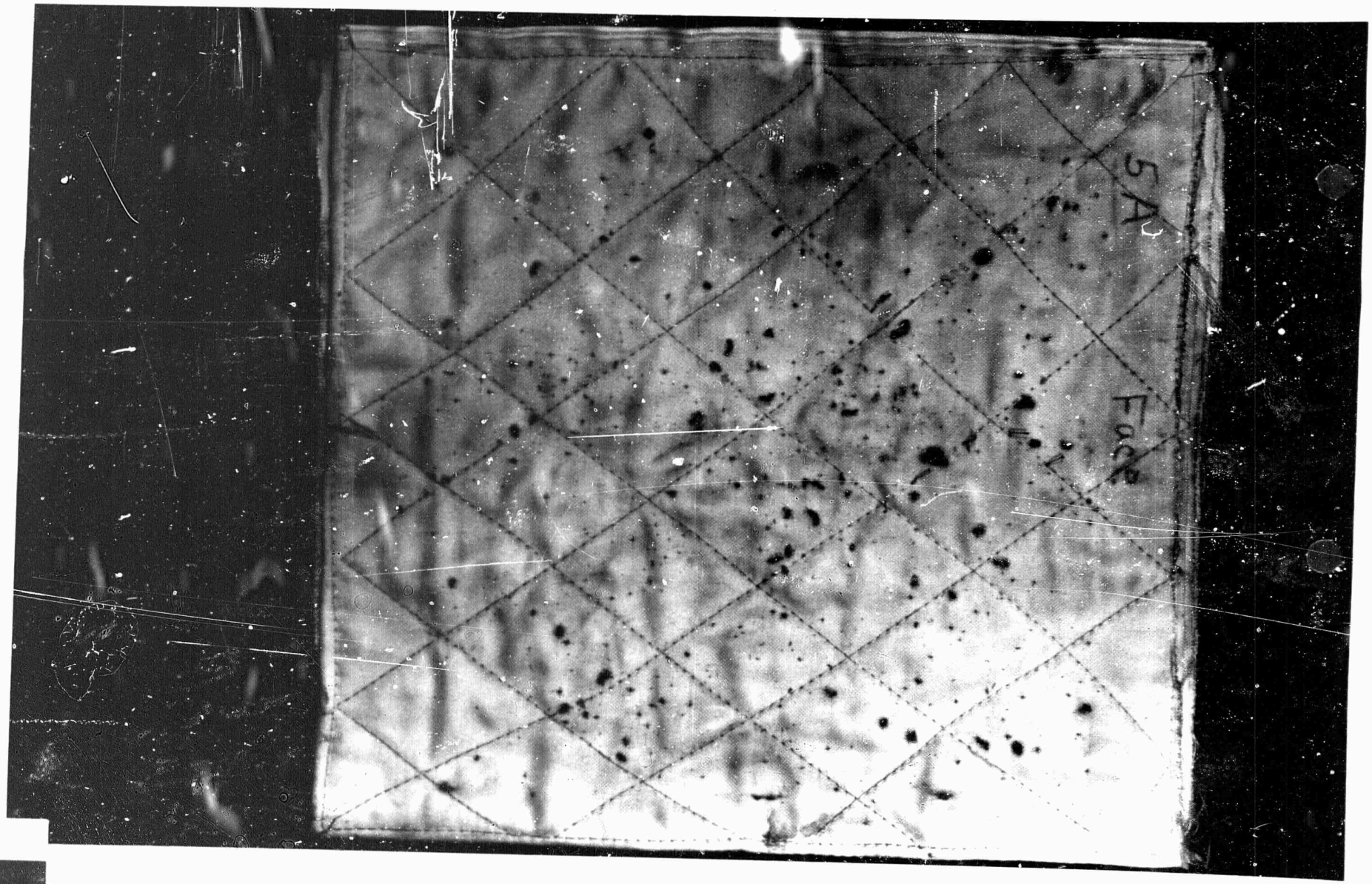
Panel	Unit Wt	Bullet	Charge	Str.Vel.	Condition of Plate	Trigger Plate Dispersion	Av. Ga.
1	2.78	20MM	423	2707	8 Holes	7" Hole 3" High 1" Left	0."121
2	2.78	"	423	2707	7 Holes	7½ Hole 2" High	0."123
3	2.78	"	423	2714	10 Holes	8½ Hole 5" High 3" Right	0."123
4	2.78	"	423	2712	10 Holes	8" Hole 1" High 3" Left	0."123
5	2.78	"	423	2714	9 Holes	7½ Hole 4" High 1" Right	0."122
6	2.78	"	423	2704	6 Holes	7½ Hole 1" 2" Left	0."123

Note: Ballistic Test Performed: Ambient temperature 86°F

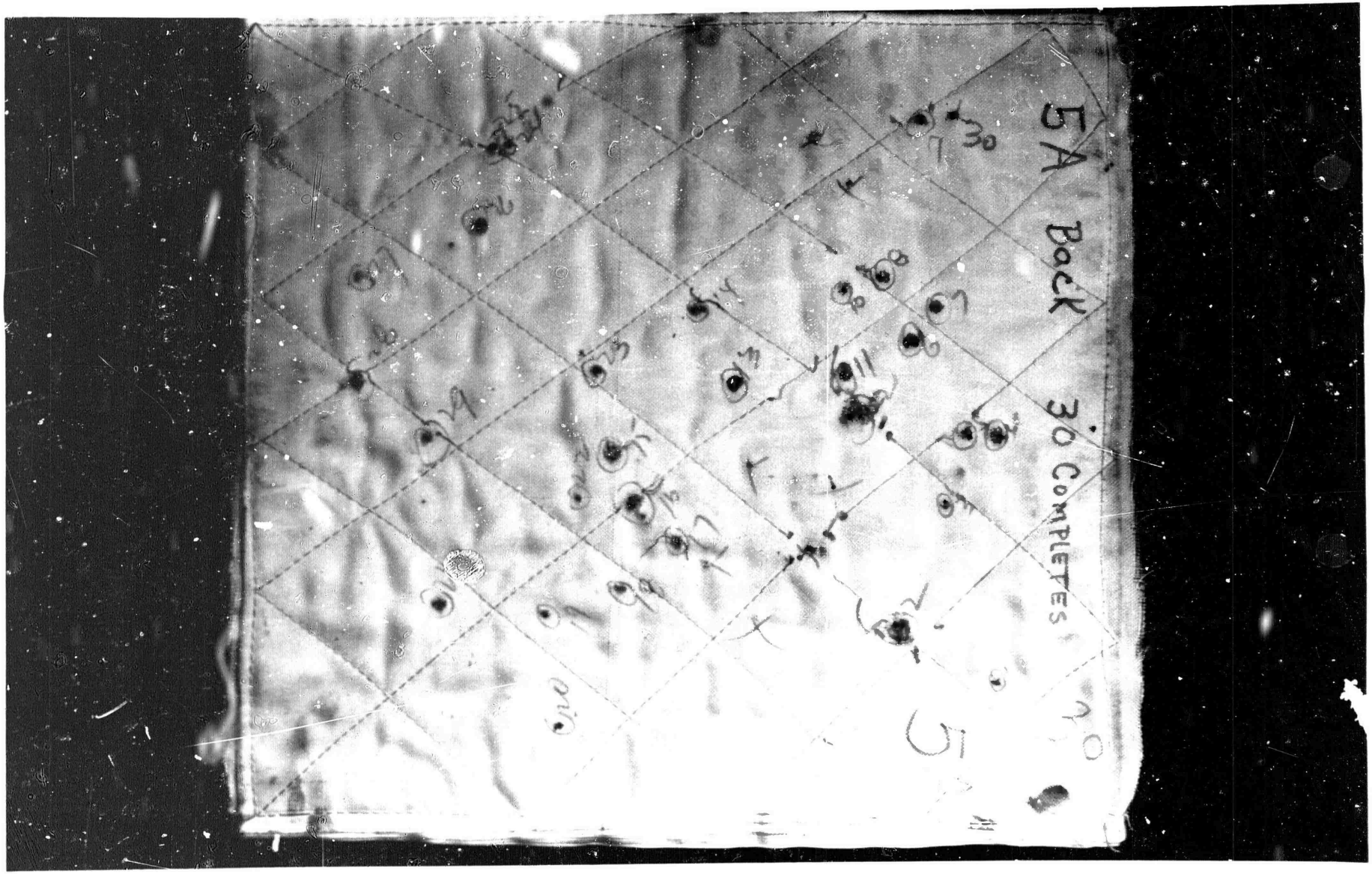
NP9 42687 Fragment Resistant Armor Panel Unbonded Nylon basket weave cloth, tested with 20mm HE Forward Fragment Spray. Panel No. - 5A, Plies - 15, Ave. wt. lbs./ft.^{2} - 1.30, No. of Penetrations - 30. Front View.
1 Sept. 1950

Figure 1

RESTRICTED



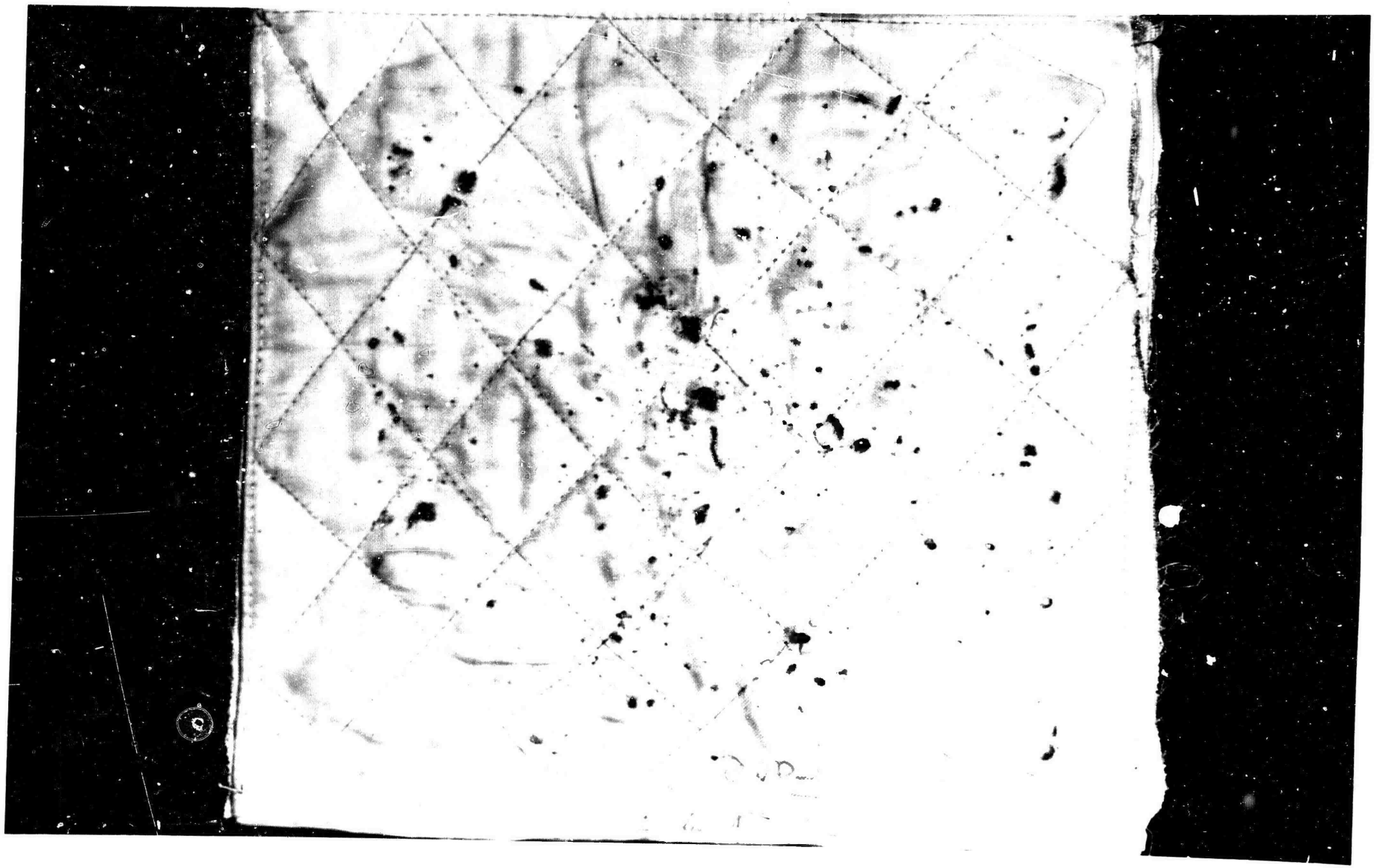
NP9 42688 Fragment Resistant Armor Panel Unbonded Nylon basket weave cloth, tested with 20mm HE Forward Fragment Spray. Panel No. - 5A, Plies - 15, Ave. wt. lbs./ft.^{2} - 1.30, No. of Penetrations - 30. Back View.
1 Sept. 1950 Figure 2 RESTRICTED



WP9 42689 Fragment Resistant Armor Panel Unbonded Nylon basket weave cloth, tested with 20mm HE Forward Fragment Spray. Panel No. - 4B, Plies - 21, Ave. wt. lbs./ft.2 - 1.82, No. of Penetrations - 16. Front View.
1 Sept. 1950

Figure 3

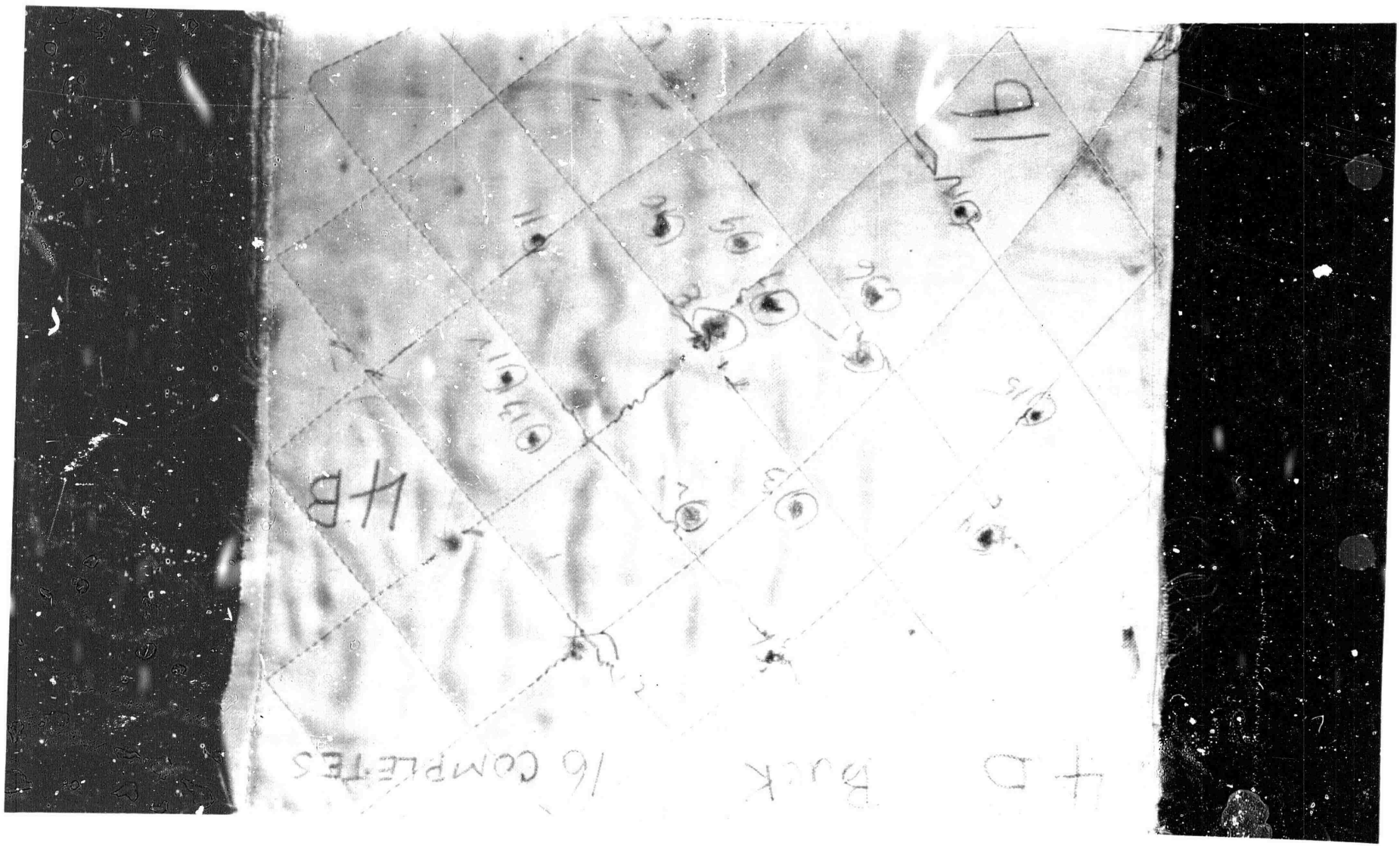
RESTRICTED



NP9 42690 Fragment Resistant Armor Panel Unbonded Nylon basket weave cloth, tested with 20mm HE Forward Fragment Spray. Panel No. - 4B, Plies - 21, Ave. wt. lbs./ft.^{2} - 1.82, No. of Penetrations - 16. Back View.
1 Sept. 1950

Figure 4

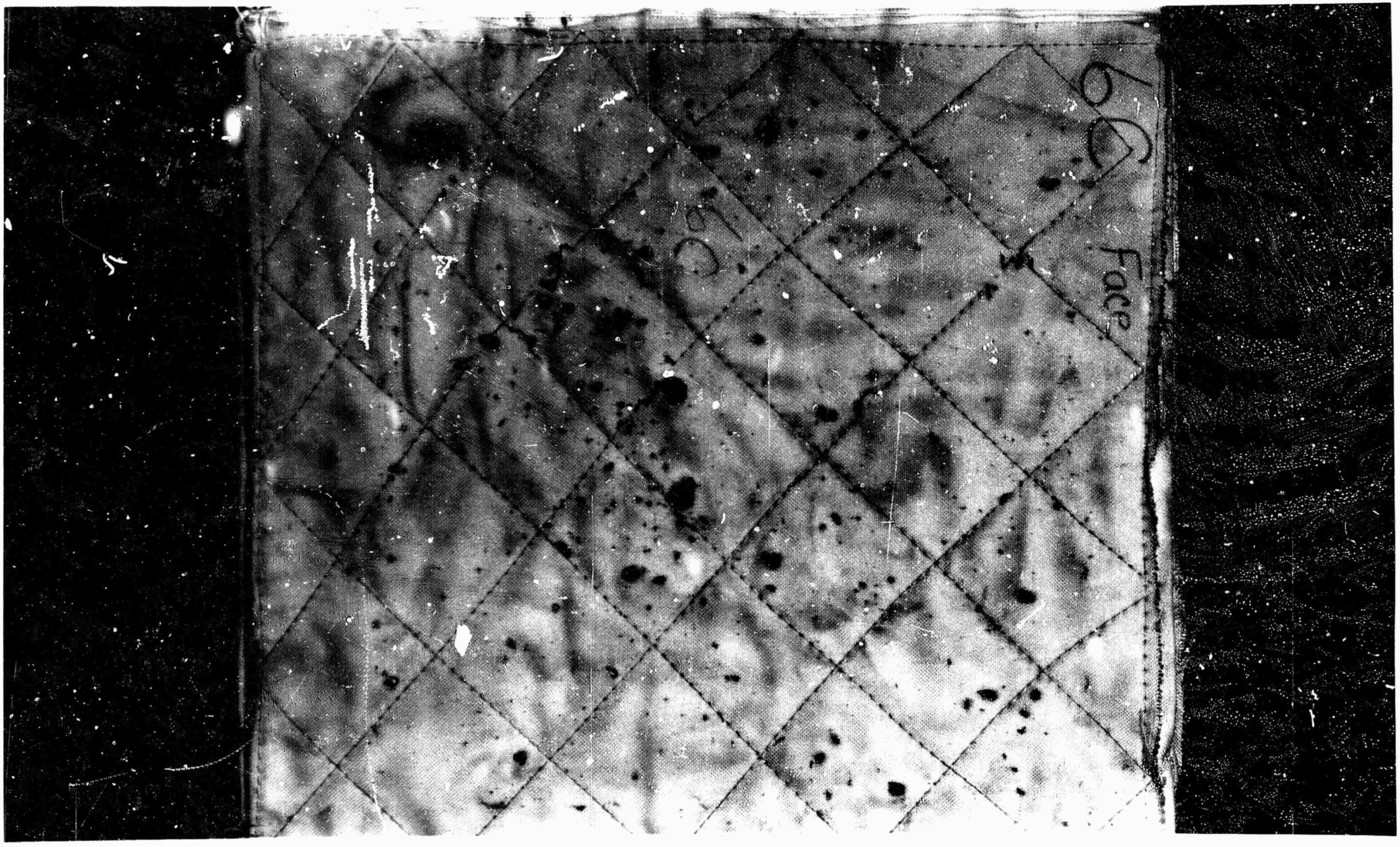
RESTRICTED



NP9 42691 Fragment Resistant Armor Panel Unbonded Nylon basket weave cloth, tested with 20mm HE Forward Fragment Spray. Panel No. - 6C, Plies - 32, Ave. wt. lbs./ft.^{2} - 2.78, No. of Penetrations -6. Front View.
1 Sept. 1950

Figure 5

RESTRICTED



NP9 42692 Fragment Resistant Armor Panel Unbonded Nylon basket weave cloth, tested with 20mm HE Forward Fragment Spray. Panel No. - 60, Plies - 32, Ave. wt. lbs./ft.^{2} - 2.78, No. of penetrations - 6. Back View.
1 Sept. 1950

Figure 6

RESTRICTED

NP9 42566

SEPT. 1950

RESTRICTED

20MM HE FORWARD FRAGMENT SPRAY VERSUS VARIOUS TYPES OF FRAGMENT RESISTANT ARMOR (18" x 18" SECTIONS)

MK. 3 PROJECTILES, MK. 26 MOD 1 FUZES
PROJECTILES DETONATED IN FLIGHT AT SERVICE VELOCITY (2700 F.S.)
ON 1/8" MILD STEEL NORMAL TO LINE OF FLIGHT TARGET PANEL
PARALLEL TO AND 3' BEHIND TRIGGER PLATE

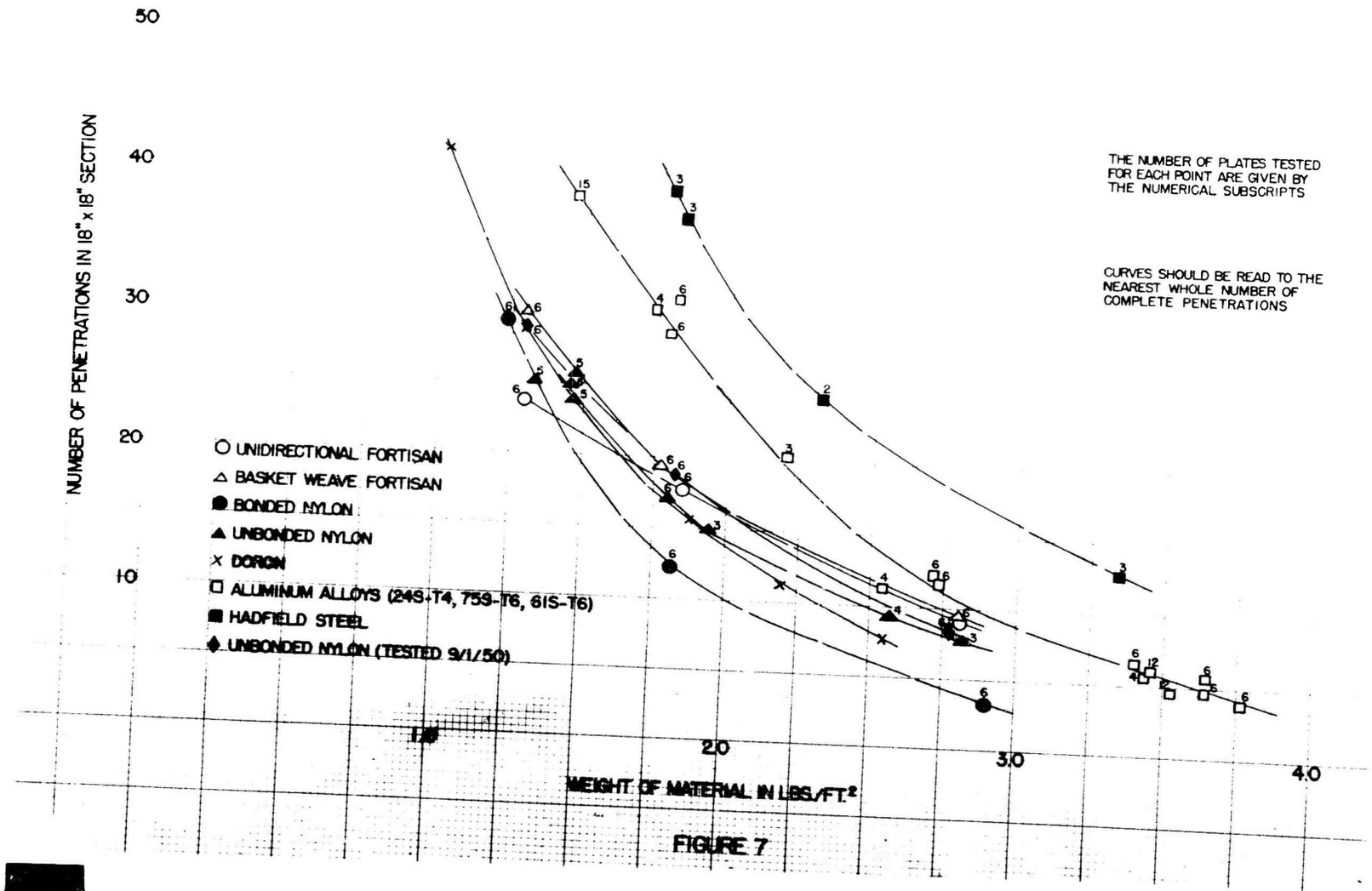


FIGURE 7

Unbonded Nylon Fragment Armor Fabric
Ballistic Surveillance Test of

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DISTRIBUTION

Bureau of Ordnance	
Ad3	1
Re3	1
Re3a	2
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Bureau of Aeronautics Aer-AR-82	1
Bureau of Aeronautics Aer-AE-44	2
Chief of Ordnance, Department of the Army Attn: ORDTX-AR	2
Commanding General, Aberdeen Proving Ground, Aberdeen, Md. Attn: Technical Information Section Development and Proof Services	1
Naval Research Laboratory Attn: Dr. George Irwin	1
Navy Research Section, Library of Congress Washington 25, D. C. (Via BUORD Re3a)	2
Naval Ordnance Laboratory Attn: Explosive Division	1
Picatinny Arsenal, Dover, N. J. Attn: Technical Division	1
New Mexico School of Mines Research and Development Division Sorocco, New Mexico	1
Watertown Arsenal Watertown, Mass.	1
Local:	
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TL	1
TK	1
File	1

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NPG REPORT NO. 660

Unbonded Nylon Fragment Armor Fabric
Ballistic Surveillance Test of

PART A

SYNOPSIS

1. The Bureau of Aeronautics is interested in utilizing in flak jackets and curtains some Nylon fabric that has been in storage for some time. This test was conducted to determine the fragment resisting properties with the 20mm HE forward fragment spray test of basket weave Nylon which had been in storage and to compare the results with the results obtained on similar materials tested previously, namely unbonded Nylon.

2. The unbonded Nylon panels, fabricated from basket weave cloth that had been in storage for some time, as tested herein exhibited satisfactory performance against 20mm HE forward spray fragments at weights of 1.30, 1.82 and 2.78 lbs./ft.^{2}.

3. At the lighter weights of 1.30 and 1.82 lbs./ft.^{2}, the performance of the subject Nylon panels was slightly inferior to that of unbonded Nylon tested previously. However, at a weight of 2.78 lbs./ft.^{2} the performance was equivalent to that of unbonded Nylon tested previously.

4. The results obtained in this test indicate that the quality of the subject Nylon fabric is suitable for fabrication into flak jackets and curtains.

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Unbonded Nylon Fragment Armor Fabric
Ballistic Surveillance Test of

TABLE OF CONTENTS

Unbonded Nylon Fragment Armor Fabric
Ballistic Surveillance Test of

- -

PART B

INTRODUCTION

1. AUTHORITY:

The subject test, authorized by reference (a), was conducted under Bureau of Aeronautics TED Project NPG AR 8208 as established by reference (b).

2. REFERENCES:

a. BUAER ltr (Aer-AE-44) 67076 of 25 August 1950 to NAVPROV via BUORD. End 1 by BUORD Re8a-FHS:ejb F41-1(HG) of 12 September 1950.
b. BUAER ltr (Aer-AR-82) 81624 of 3 August 1949 to NAVPROV via BUORD. End 1 by BUORD S13-1(4)Re3 of 10 August 1949 to NAVPROV.
c. BUORD Spec O.S. 3563.
d. NAVPROV ltr S13-1(5)(EXO 77576) of 10 November 1944 to BUORD.
e. NAVPROV ltr S13-1(5)(EXO 74074) of 16 September 1944 to BUORD.
f. NAVPROV ltr S13-1(5)(EPO 84791) of 29 March 1945 to BUORD.
g. NAVPROV ltr S13-1(5)(EPO 91528) of 12 July 1945 to BUORD.
h. NAVPROV ltr S13-1(5)(EPO 94337) of 15 April 1946 to BUORD.
i. NAVPROV ltr S13-1(5)(EPO 89990) of 7 June 1945 to BUORD.
j. NPG Report No. 26 of 13 May 1948.
k. NPG Report No. 392 of 5 October 1949.

3. BACKGROUND:

Fragment resistant armor materials including unbonded Nylon of various types have been tested previously at the Naval Proving Ground. A quantity of Nylon basket weave cloth has been stored for some time at the Aviation Supply Office, Philadelphia. The Bureau of Aeronautics is presently interested in utilizing this material for flak jackets and curtains. Thus, the Naval Proving Gound was requested to fabricate various weight panels from this material and determine the fragment resisting properties thereof.

Unbonded Nylon Fragment Armor Fabric
Ballistic Surveillance Test of

4. OBJECT OF TEST:

This test was conducted to determine the fragment resisting properties with the 20mm HE forward fragment spray test of basket weave Nylon which had been in storage and to compare the results with the results obtained on similar materials tested previously.

5. PERIOD OF TEST:

a.	Date of Authorizing Letter	25 August 1950
b.	Date Material Received	11 August 1950
c.	Date Commenced Test	1 September 1950
d.	Date Test Completed	1 September 1950

PART C

DETAILS OF TEST

6. DESCRIPTION OF ITEM UNDER TEST:

Approximately 800 feet of basket weave Nylon cloth reported to be NFD-202/1 by the Bureau of Aeronautics was received at the Naval Proving Ground on 11 August 1950. This material was found to weigh approximately .087 lbs./ft.^{2}. Test panels of 1.30, 1.82 and 2.78 lbs./ft.^{2} were processed from this material. The panels processed were as follows:

No. of Panels	No. of Plies	Size	Av. Weight lbs./ft.^{2}
6	15	23" x 24"	1.30
6	21	23" x 24"	1.82
6	32	23" x 24"	2.78

7. DESCRIPTION OF TEST EQUIPMENT:

a. Ammunition and Gun.

20mm HE projectiles Mk. 3 with fuzes Mk. 26 Mod. 1.
Gun No. 850003.

b. Triggering Plates.

Cold rolled strip steel (2' x 2' x 0"125 ± .005) in dead soft temper at Rockwell B hardness 45 ± 7.

c. A 150' range with target mounting jig and velocity measuring equipment.

8. PROCEDURE:

The test panels were masked off to leave exposed sections 18" x 18". A total of six (6) 18" x 18" sections of each weight were given the 20mm HE forward fragment spray test in accordance with the procedure outlined in paragraph F-7 of reference (c). This procedure consists of testing each 18" x 18" exposed section with fragments from one 20mm HE Mk. 3 projectile fuzed with a Mk. 26 Mod. 1 fuze detonated in flight at service velocity on a 0"125 mild steel plate 3 feet forward of the section. The striking velocity of the projectile on the triggering plate was held to 2700 ± 50 ft./sec.. The triggering plate and test section were both placed normal to the line of fire and positioned so that the projected line of fire passed through the center of both.

9. RESULTS AND DISCUSSION:

a. The results are given in detail in Appendix (A) and are summarized below:

No. of Plies	Average Weight lbs./ft.^{2}	Penetrations in 18" x 18" Sections (Av. of 6)	Penetrations Average of 3 Poorest of 6 Tested	Allowed Ref. (c) 3 Poorest	Remarks
15	1.30	29	32	35	Passed
21	1.82	18.7	21.7	22	Passed
32	2.78	6.3	9.7	8	Failed

b. Photographs of representative panels after ballistic test are contained in Appendix (B).

c. The test panels assembled from the Nylon basket weave cloth passed the ballistic requirements of reference (c) at normal temperature by (+3) penetrations at 1.30 lbs./ft.^{2} and by (+0) penetrations at 1.82 lbs./ft.^{2}, but failed by (-2) penetrations at 2.78 lbs./ft.^{2}.

d. In Appendix (C) the number of complete penetrations of 18" x 18" sections of various fragment resistant armors are plotted against the weight of each material in lbs./ft.^{2}. The complete penetrations versus weight curves as drawn in Appendix (C) indicates the efficiency of the various materials in stopping 20mm HE forward spray fragments. Thus, from these curves a comparison of the performance of the Nylon cloth as tested herein and similar type Nylon cloth tested previously can be obtained. These curves are based on data obtained from sources as listed below:

Material	Source of Data
Unbonded Nylon (NFD-202/1)	As tested herein
Fortisan Basket Weave	Reference (k)
Fortisan Unidirectional	Reference (k)
Bonded Nylon	Reference (d)
Unbonded Nylon	Reference (e),(f),(g),(h)
Doron	Acceptance and experimental ballistic tests of over 2000 panels performed in 1944 and 1945
Aluminum Alloy	References (e),(i),(j)
Hadfield Steel	Reference (d)

e. Appendix (C) shows that at weights of 1.30 and 1.82 lbs./ft.^{2} the subject unbonded basket weave Nylon panels had slightly more fragment penetrations than did unbonded Nylon panels tested previously. At a weight of 2.78 lb./ft.^{2} the number of penetrations were approximately the same for the subject unbonded Nylon and unbonded Nylon tested previously.

Unbonded Nylon Fragment Armor Fabric
Ballistic Surveillance Test of

f. The results of the subject test were reported to Mr. R. Temple (Aer-AE-44) by telephone on 4 September 1950 in order to facilitate action as regards to fabrication of flak jackets and curtains from the subject Nylon fabric.

PART D

CONCLUSIONS

10. a. The unbonded Nylon panels, fabricated from basket weave cloth that had been in storage for some time, as tested herein exhibited satisfactory performance against 20mm HE forward spray fragments at weights of 1.30, 1.82 and 2.78 lbs./ft.^{2}.

b. At the lighter weights of 1.30 and 1.82 lbs./ft.^{2}, the performance of the subject Nylon panels was slightly inferior to that of unbonded Nylon tested previously. However, at a weight of 2.78 lbs./ft.^{2} the performance was equivalent to that of unbonded Nylon tested previously.

c. The results obtained in this test indicate that the quality of the subject Nylon fabric is suitable for fabrication into flak jackets and curtains.

NPG REPORT NO. 660

Unbonded Nylon Fragment Armor Fabric
Ballistic Surveillance Test of

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B. W. SARVER
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Terminal Ballistics Officer

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Commander, Naval Proving Ground

C. H. ANDERSON
Captain, USN
Ordnance Officer
By direction

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